



Data collected for:
Oregon Department of Geology and Mineral Industries

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Project Overview

QSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data describing the Oregon LiDAR Consortium's (OLC) Silver Creek Study Area. The Silver Creek delivered total area flown (TAF) shown in Figure 1 encompasses approximately 421,474 acres.

The collection of high resolution geographic data is part of an ongoing pursuit to amass a library of information accessible to government agencies as well as the general public.

LiDAR data acquisition occurred between August 27 and September 11, 2017. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter. Final products are listed on page three.

QSI acquires and processes data in the most current, NGS-approved datums and geoid. For Silver Creek, all final deliverables are projected in Oregon Lambert, endorsed by the Oregon Geographic Information Council (OGIC),¹ using the NAD83 (2011) horizontal datum and the NAVD88 (Geoid 12B) vertical datum, with units in International feet.

Table 1: Silver Creek delivery details

OLC Silver Creek	
Acquisition Dates	August 27 - September 11, 2017*
Area of Interest	421,474 acres
Projection	OGIC Lambert
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12B)
Units	International Feet

*See page four for specific acquisition dates.

¹ <http://www.oregon.gov/DAS/EISPD/GEO/pages/coordination/projections/projections.aspx>

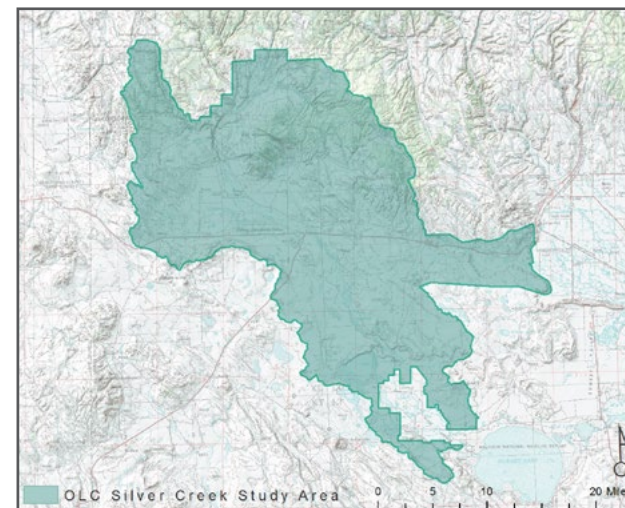


Figure 1: OLC Silver Creek study area

Deliverable Products

Table 2: Products delivered for the OLC Silver Creek study area.

OLC Silver Creek Projection: Oregon Statewide Lambert, Lambert Conformal Conic Horizontal Datum: NAD83 (2011) Vertical Datum: NAVD88 (GEOID12B) Units: International Feet	
Points	LAS v 1.2 tiled by 0.75 minute USGS quadrangles <ul style="list-style-type: none"> • Default (1) and ground (2) classified points • RGB color extracted from NAIP imagery • Intensities
Rasters	3 foot ESRI GRID tiled by 7.5 minute USGS quadrangles <ul style="list-style-type: none"> • Bare earth model • Highest hit model 1.5 foot GeoTiffs tiled by 7.5 minute USGS quadrangles <ul style="list-style-type: none"> • Intensity images
Vectors	Shapefiles (.shp) <ul style="list-style-type: none"> • Data extent (total area flown - TAF) • TAF tile index of 0.75 minute USGS quadrangles • TAF tile index of 7.5 minute USGS quadrangles
Acquisition Vectors*	<ul style="list-style-type: none"> • Ground control points (used for calibration) • Reserved ground survey points (used for accuracy testing) • Monuments • Acquisition flightlines
Metadata	<ul style="list-style-type: none"> • FGDC compliant metadata for all data products

*Acquisition vectors delivered in Universal Transverse Mercator (UTM) 11; NAD83 (2011); NAVD99 (Geoid12B), meters.



Aerial Acquisition

LiDAR Survey

The LiDAR survey utilized a Leica ALS 80 sensor mounted in a Cessna Grand Caravan. For system settings, please see Table 3. These settings are developed to yield points with an average native density of greater than eight pulses per square meter over terrestrial surfaces.

The native pulse density is the number of pulses emitted by the LiDAR system. Some types of surfaces such as dense vegetation or water may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and lightly vary according to distributions of terrain, land cover, and water bodies. The study area was surveyed with opposing flight line side-lap of greater than 60 percent with at least 100 percent overlap to reduce laser shadowing and increase surface laser painting. The system allows up to four range measurements per pulse, and all discernible laser returns were processed for the output data set.

To solve for laser point position, it is vital to have an accurate description of aircraft position and attitude. Aircraft position is described as x, y, and z and measured twice per second (two hertz) by an onboard differential GPS unit. Aircraft attitude is measured 200 times per second (200 hertz) as pitch, roll, and yaw (heading) from an onboard inertial measurement unit (IMU).

Table 3: OLC Silver Creek acquisition specifications

OLC Silver Creek Acquisition	
Sensors Deployed	Leica ALS 80
Aircraft	Cessna Grand Caravan
Survey Altitude (AGL)	1,500 m
Pulse Rate	357.2 kHz
Pulse Mode	Multi (MPiA)
Field of View (FOV)	40°
Scan Rate	52.0 Hz
Overlap	100% overlap with 60% sidelap



Figure 2: Silver_Creek_01 monument

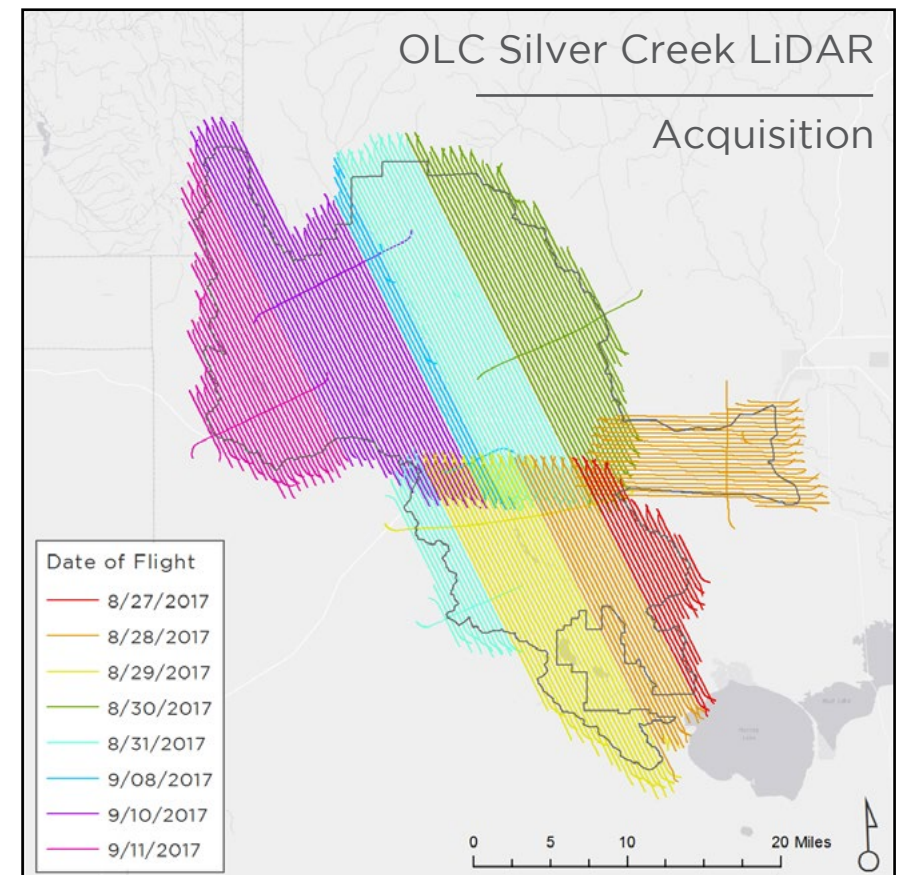


Figure 3: OLC Silver Creek acquisition specifications

Ground Survey

Ground control surveys were conducted to support the airborne acquisition. Ground survey data, including monumentation, ground control points (GCPs), and ground survey points (GSPs), are used to geospatially correct the aircraft positional coordinate data and to perform quality assurance checks on final LiDAR data.

Instrumentation

All Global Navigation Satellite System (GNSS) static surveys utilized Trimble R7 GNSS receivers with Zephyr Geodetic Model 2 RoHS antennas. Rover surveys for GCP and GSP collection were conducted with Trimble R10 GNSS receivers. Two monuments set by QSI staff, as well as two existing monuments, were utilized for flight support and collection of GCPs and GSPs. See Table 5 for specifications of equipment used.

Monumentation

The spatial configuration of ground survey monuments provided redundant control within 20 nautical miles of the mission areas for LiDAR flights. Monuments were also used for collection of ground control points and ground survey points. Monument locations were selected with consideration for satellite visibility, field crew safety, and optimal location for GCP/GSP coverage. New monumentation was set using 5/8" x 30" rebar topped with stamped 2-1/2" aluminum caps. QSI's professional land surveyor, Evon Silvia (OR PLS #81104) oversaw and certified the establishment of all monuments.

To correct the continuously recorded onboard measurements of the aircraft position, QSI concurrently conducted multiple static Global Navigation Satellite System (GNSS) ground surveys (1 Hz recording frequency) over each monument. During post-processing, the static GPS data were triangulated with nearby Continuously Operating Reference Stations (CORS) using the Online Positioning User Service (OPUS) for precise positioning. Multiple independent sessions over the same monument were processed to confirm antenna height measurements and to refine position accuracy. Table 4 provides the list of monuments established and utilized in the Silver Creek study area.

Methodology

Ground control points and ground survey points were collected using real time kinematic (RTK), post-processed kinematic (PPK), and Fast Static (FS) techniques. For RTK surveys, a base receiver was positioned at a nearby monument to broadcast a kinematic correction to a roving receiver; for PPK and FS surveys, however, these corrections were post-processed. RTK and PPK surveys recorded observations for a minimum of five seconds on each GCP/GSP in order to support longer baselines for post-processing; FS surveys record observations for up to fifteen minutes on each point in order to support longer baselines for post-processing. All GCP and GSP measurements were made during periods with a Position Dilution of Precision (PDOP) no greater than 3.0 and in view of at least six satellites for both receivers. Relative errors for the position were required to be less than 1.5 centimeters horizontal and 2.0 centimeters vertical in order to be accepted.

In order to facilitate comparisons with high quality LiDAR data, GCP and GSP measurements were not taken on highly reflective surfaces such as center line stripes or lane markings on roads. GCPs and GSPs were taken no closer than one meter to any nearby terrain breaks such as road edges or drop offs. GCPs and GSPs were collected within as many flight lines as possible; however, the distribution depended on ground access constraints and may not be equitably distributed throughout the study area.

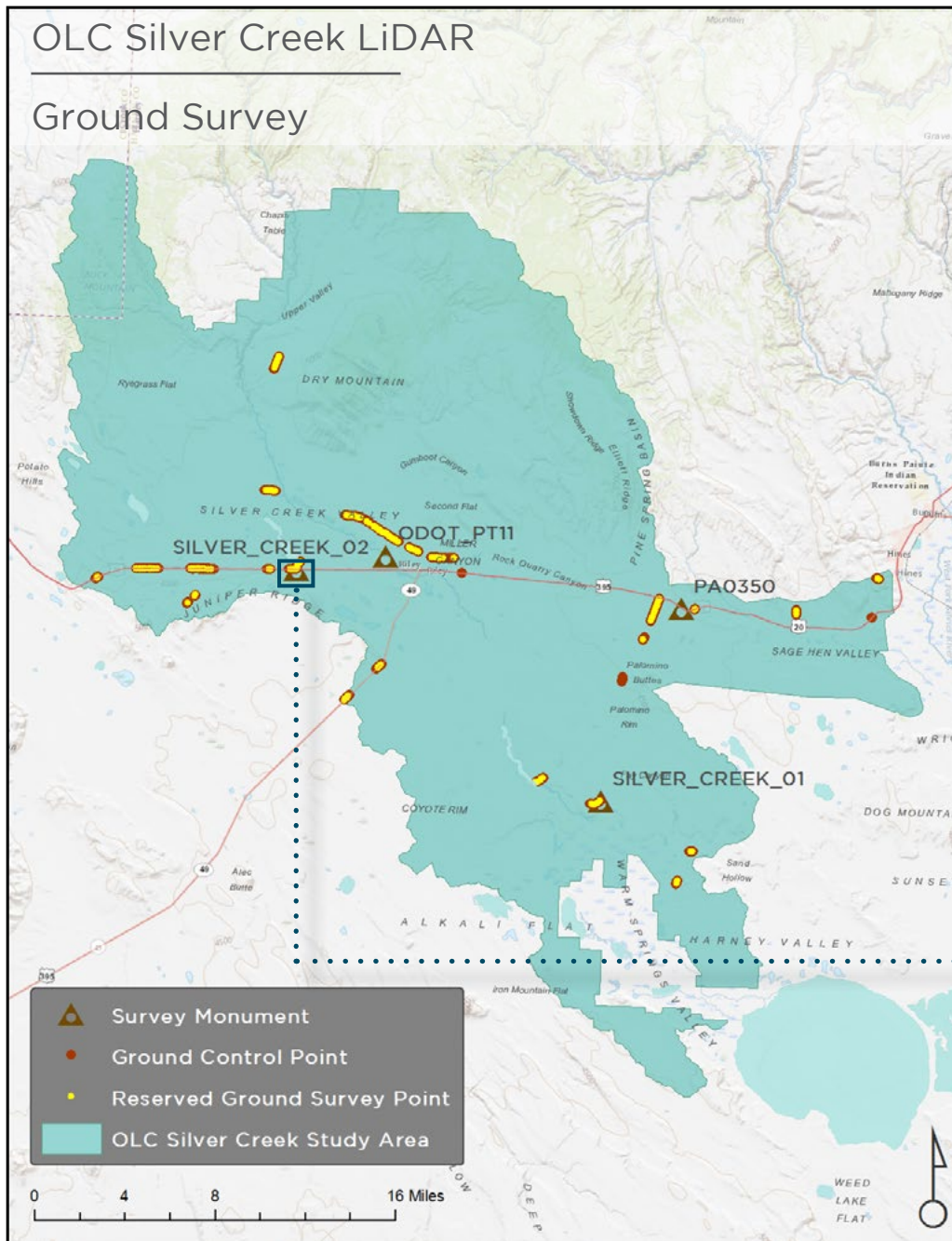


Figure 4: Silver Creek study area ground control

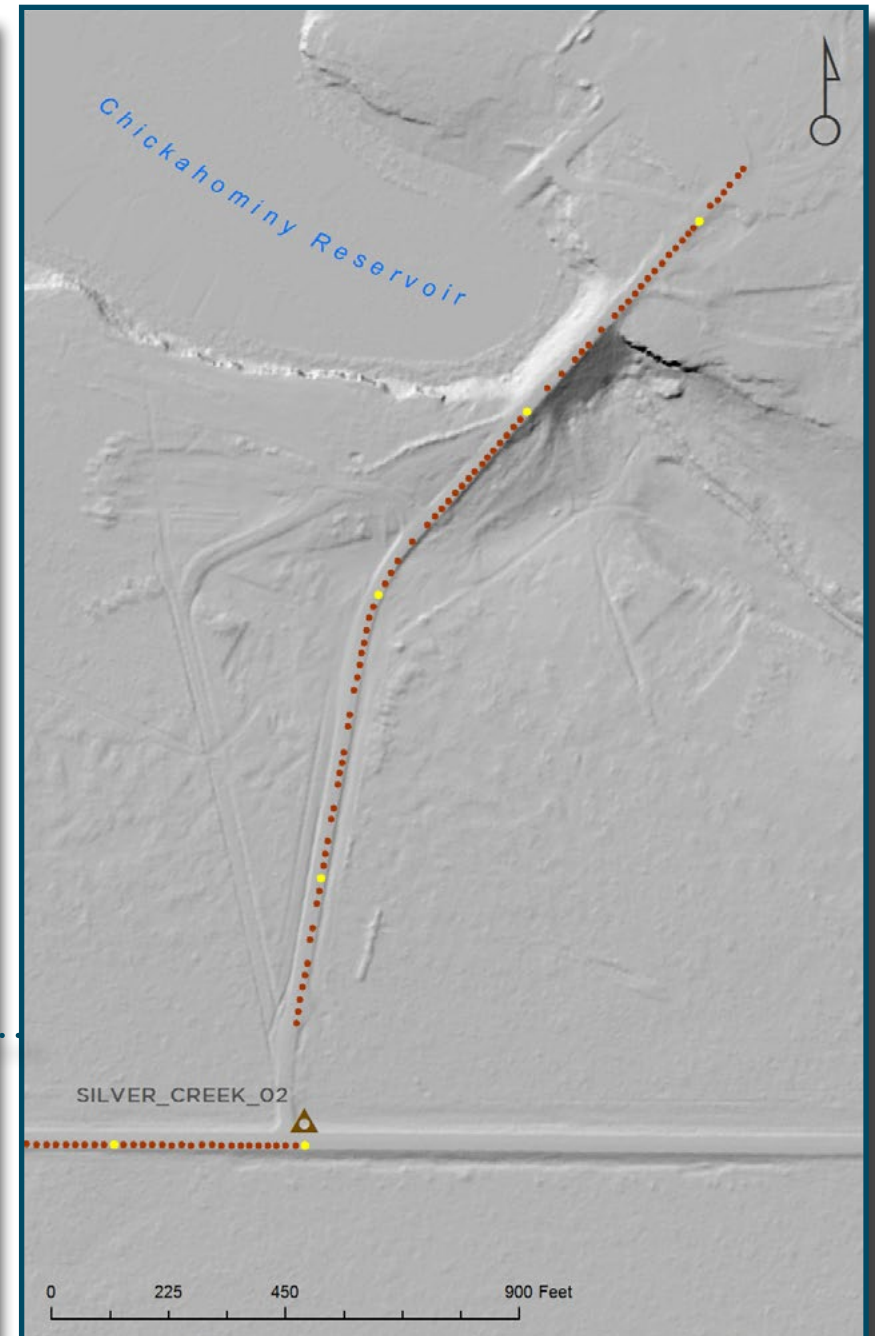


Figure 5: Detailed view of Silver Creek ground control.



Figure 6: Zephyr GNSS Geodetic Model 2 antenna set up over NGS monument PA0350.

Table 4: Silver Creek monuments. Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 heights derived from GNSS using Geoid 12B.

	PID	Latitude	Longitude	Ellipsoid Height (m)	Orthometric Height (m)
QSI Monuments	SILVER_CREEK_01	43° 23' 50.14364"	-119° 20' 27.88703"	1287.049	1306.548
	SILVER_CREEK_02	43° 32' 25.20388"	-119° 36' 55.30865"	1291.366	1310.823
Existing Monuments	PA0350	43° 31' 20.17245"	-119° 16' 27.45790"	1330.322	1349.526
	ODOT_PT11	43° 33' 03.15542"	-119° 32' 12.87121"	1272.914	1292.324

Table 5: Ground survey instrumentation

Instrumentation			
Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R7 GNSS	Zephyr GNSS Geodetic Model 2 RoHS	TRM57971.00	Static
Trimble R10 GNSS	Integrated Antenna	TRM_R10	Rover

Table 6: Monument accuracy

Monument Accuracy	
FGDC-STD-007.2-1998 Rating	
St Dev NE	2 cm
St Dev Z	2 cm

LiDAR Accuracy Assessments

Relative Accuracy

Relative vertical accuracy refers to the internal consistency of the data set and is measured as the divergence between points from different flightlines within an overlapping area. Divergence is most apparent when flightlines are opposing. When the LiDAR system is well calibrated the line to line divergence is low (<10 centimeters). Internal consistency is affected by system attitude offsets (pitch, roll, and heading), mirror flex (scale), and GPS/IMU drift

Relative accuracy statistics, reported in Table 7 are based on the comparison of 267 full and partial flightlines and over 11 billion sample points.

Table 7: Relative accuracy

Relative Accuracy Calibration Results		
Project Average	0.042 m	0.137 ft
Median Relative Accuracy	0.039 m	0.129 ft
1 σ Relative Accuracy	0.045 m	0.149 ft
2 σ Relative Accuracy	0.061 m	0.200 ft
Flightlines	n = 267	
Sample points	11,061,822,746	

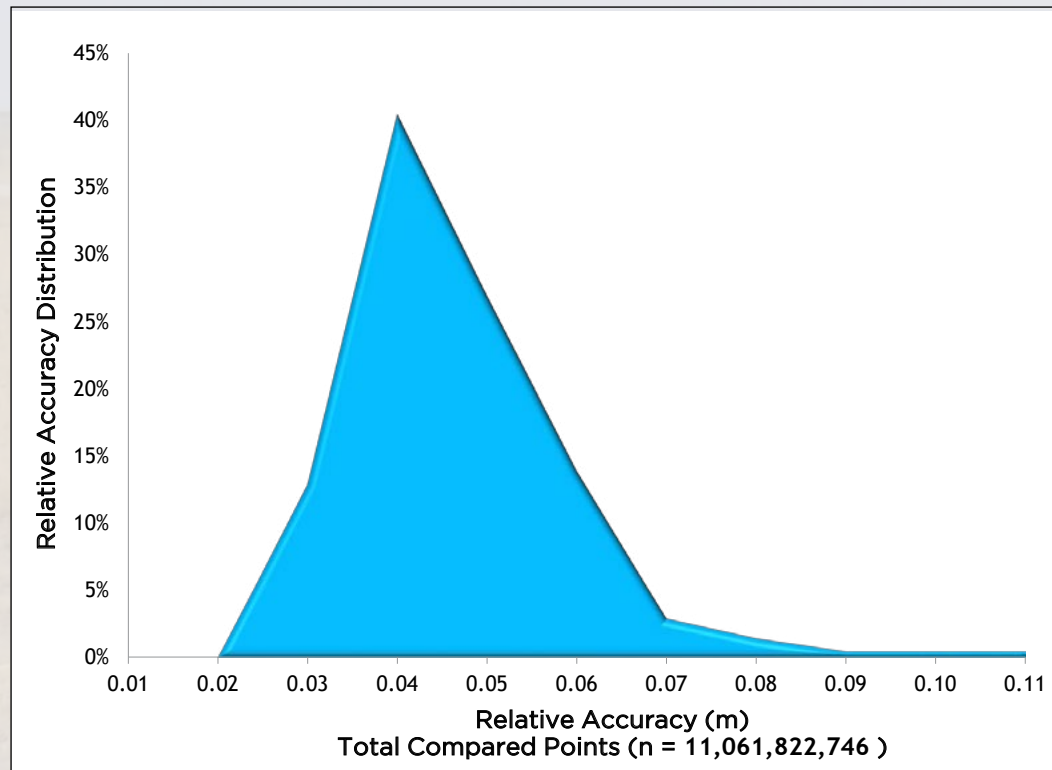


Figure 7: Relative accuracy based on 267 flightlines.



Vertical Accuracy

Vertical Accuracy reporting is designed to meet guidelines presented in the National Standard for Spatial Data Accuracy (NSSDA) (FGDC, 1998) and the ASPRS Positional Accuracy Standards for Digital Geospatial Data V1.0 (ASPRS, 2014). The statistical model compares known reserved ground survey points (GSPs) to the ground model, triangulated from the neighboring laser points. Vertical accuracy statistical analysis uses reserved ground survey points in open areas where the LiDAR system has a “very high probability” that the sensor will measure the ground surface and is evaluated at the 95th percentile.

For the OLC Silver Creek study area, a total of 3,265 ground control points were collected and used for calibration of the LiDAR data. An additional 172 ground survey points were collected and reserved for independent verification, resulting in a non-vegetated vertical accuracy (NVA) of 0.092 meters, or 0.303 feet.

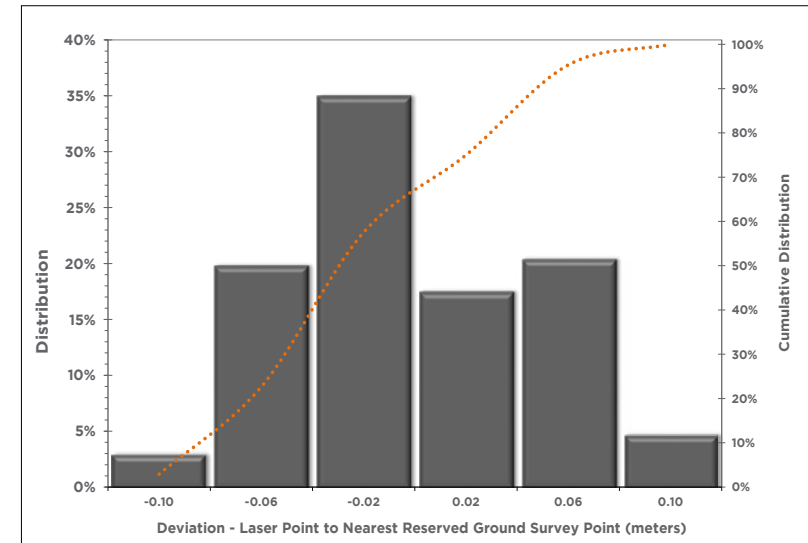


Figure 8: Vertical accuracy distribution

Table 8: Vertical accuracy results

Non-vegetated Vertical Accuracy	Tested against TIN	
Sample Size (n)	172 Reserved Ground Survey Points	
Vertical Accuracy at 95% confidence level (RMSE*1.96)	0.092 m	0.303 ft
Root Mean Square Error	0.047 m	0.154 ft
Standard Deviation	0.053 m	0.172 ft
Minimum Deviation	-0.111 m	-0.364 ft
Maximum Deviation	0.079 m	0.259 ft

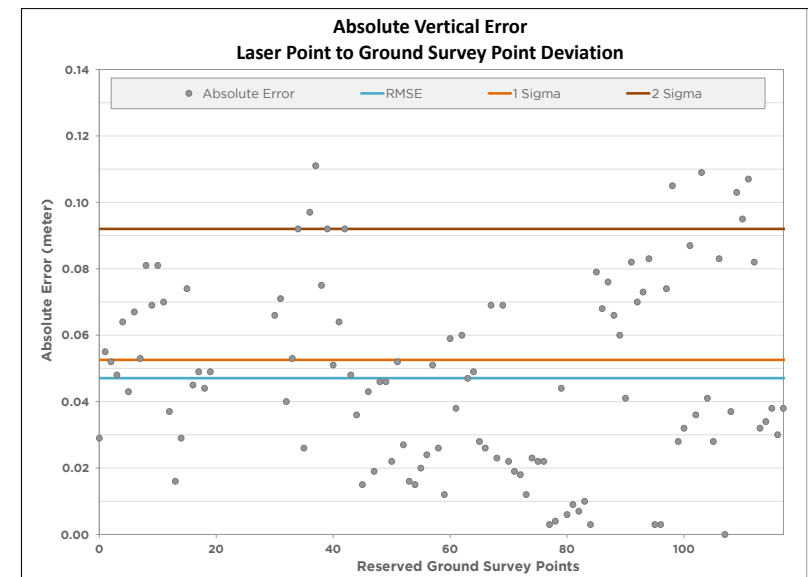


Figure 9: Reserved ground survey point absolute error

Density

Pulse Density

Final pulse density is calculated after processing and is a measure of first returns per sampled area. Some types of surfaces (e.g., dense vegetation, water) may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and vary according to terrain, land cover, and water bodies. Density histograms and maps have been calculated based on first return laser pulse density. Densities are reported for the entire study area.

OLC Silver Creek Pulse Density

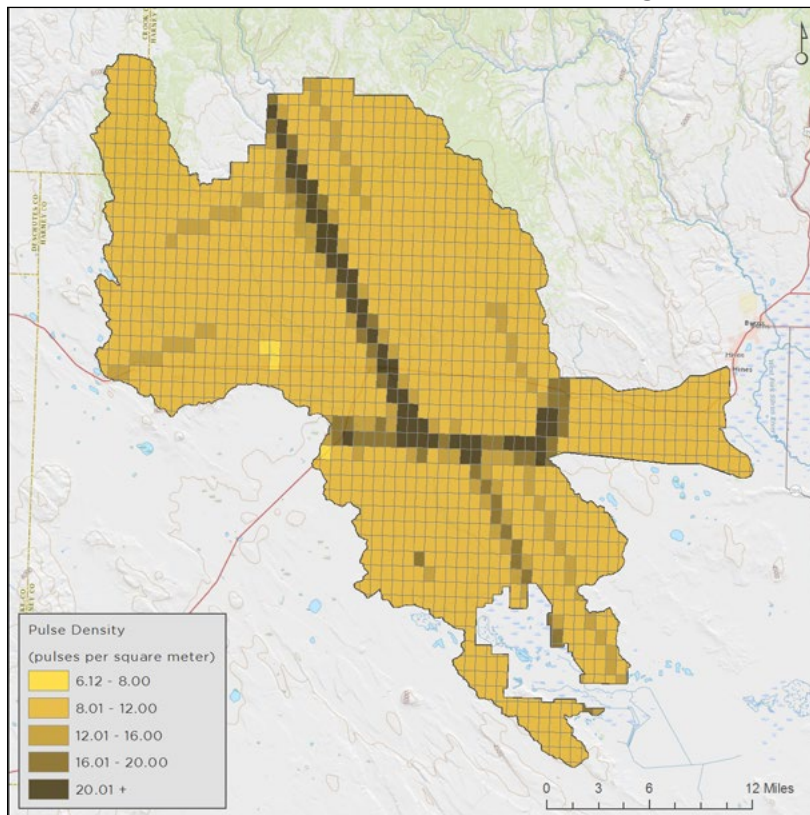


Figure 10: Average pulse density per 0.75' USGS Quad (color scheme aligns with density chart).

Table 9: Average pulse density

Average Pulse Density	pulses per square meter	pulses per square foot
	10.94	1.02

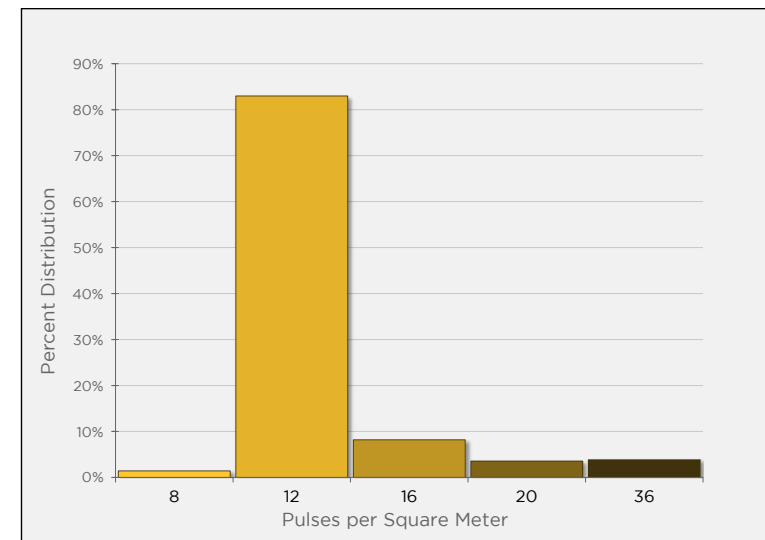


Figure 11: Pulse density distribution.

Ground Density

Ground classifications were derived from ground surface modeling. Further classifications were performed by reseeding of the ground model where it was determined that the ground model failed, usually under dense vegetation and/or at breaks in terrain, steep slopes, and at tile boundaries. The classifications are influenced by terrain and grounding parameters that are adjusted for the dataset. The reported ground density in Table 10 is a measure of ground-classified point data for the entire study area.

OLC Silver Creek Ground Density

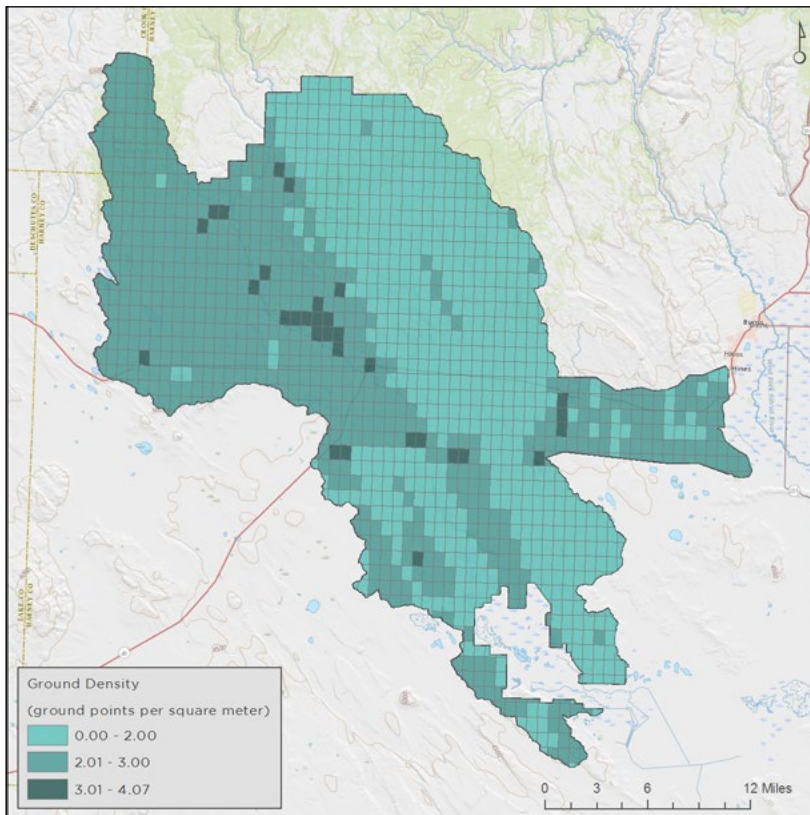


Figure 12: Average ground density per 0.75' USGS Quad (color scheme aligns with density chart).

Table 10: Average ground density

Average Ground Density	points per square meter	points per square foot
	2.07	0.19

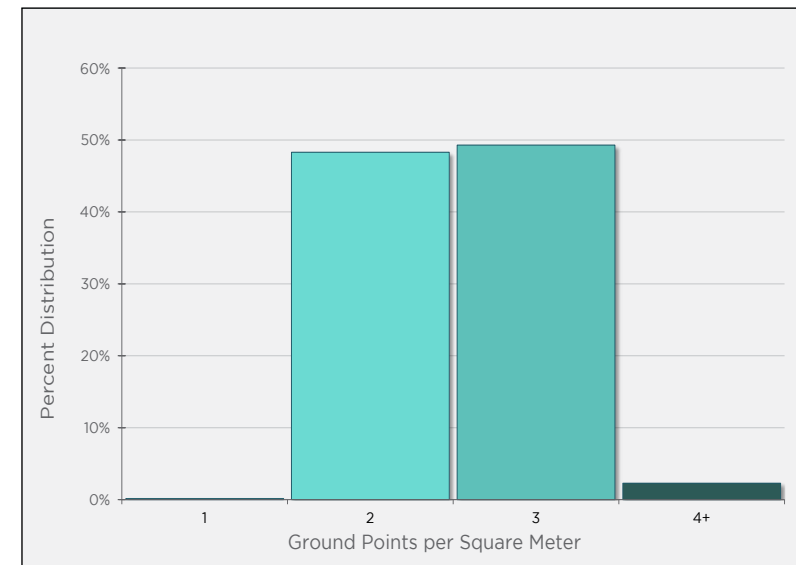


Figure 13: Ground density distribution.

Appendix A : Certifications

Quantum Spatial, Inc. provided LiDAR services for the OLC Silver Creek project as described in this report.

I, John T. English, have reviewed the attached report for completeness and hereby state that it is a complete and accurate report of this project.

John T English
John T English (Dec 15, 2017)

Dec 15, 2017

John T. English, GISP
Project Manager
Quantum Spatial, Inc.

I, Evon P. Silvia, being duly registered as a Professional Land Surveyor in and by the state of Oregon, hereby certify that the methodologies, static GNSS occupations used during airborne flights, and ground survey point collection were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between August 27 and September 11, 2017.

Accuracy statistics shown in the Accuracy Section of this Report have been reviewed by me and found to meet the "National Standard for Spatial Data Accuracy".

Evon P. Silvia

Dec 15, 2017

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PROFESSIONAL
LAND SURVEYOR

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